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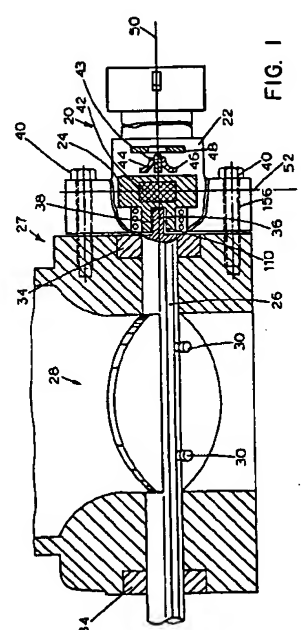
(54) Contactless angular position sensor.

(57) An angular position sensor (20, 20', 200) for sensing the angular position of a pivotally mounted device (28) includes a magnetically sensitive device (24, 210), such as a Hall effect IC, and a plurality of flux concentrators (44, 46, 206), rigidly disposed relative to the Hall effect IC (24, 210), forming an assembly. The assembly is disposed in a housing (22, 221) a fixed distance from a rotatably mounted standard magnet (42, 202) defining a fixed air gap therebetween. The magnet (42, 202) is disposed in rotatably mounted magnet holder which also acts as a drive arm (24, 210) that is adapted to be mechanically coupled to a pivotally mounted device (28). The configuration of the flux concentrators (44, 46, 206) assembled to the magnetically sensitive device (24, 210) cause the output of the Hall effect IC (24, 210) to be generally linear. In order to avoid problems associated with electrically adjustable angular position sensors, the angular position sensor (20, 20', 200) in accordance with the present invention is adjusted mechanically. In particular, a flux concentrator (48, 208), preferably having a halo shape, is disposed adjacent the magnet (42, 202). The sensor (20, 20', 200) is calibrated by varying the distance between the halo-shaped flux concentrator (48, 208) and the magnet. In one embodiment of the invention, the halo-shaped flux concentrator (48, 208) is formed to provide temperature compensation for the sensor. The sensor (20, 20') is hermetically sealed and is thus unaffected by wear or vibration. In an alternative embodiment, a circular magnet (202) with a central aperture (216) is utilized. In order to reduce the overall length of the sensor, the magnetic sensing element (218) is disposed within the central aperture (216).

FIG. 1



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The present invention relates to an angular position sensor in accordance with the pre-characterizing clause of claim 1.

Angular position sensors may be used for various purposes including sensing the angular position of a pivotally mounted device, such as a throttle valve.

Various sensors for monitoring the angular position of a pivotally mounted device, such as a butterfly valve, are known. For example, various contact type sensors, such as electromechanical potentiometers, are known. Such electromechanical potentiometers include an arcuately-shaped thick film resistive ink resistor and a movably mounted precious metal electrical wiper that is adapted to be mechanically coupled to a butterfly valve such that the relative position of the wiper relative to the resistor varies in accordance with the angular position of the butterfly valve. There are various known problems with such sensors. For example, such sensors cannot be hermetically sealed due to the dynamic seal required between the butterfly valve shaft and the wiper inside the sensor housing. As is known in the art, such dynamic seals are subject to wear over time and thus can result in degraded sensor performance in time. As such, when such sensors are used in a relatively hostile environment, such as an under-hood environment, dirt, moisture and chemical fumes are known to ingress into the sensor housing and cause degradation and erratic operation of the sensor.

Some known angular position sensors, such as the sensor disclosed in US-A-4,893,502, avoid the problem of dynamic seals. More particularly, this document discloses a modified throttle body which incorporates the sensor therewhithin. In order to provide access to the sensor, the throttle body is open on one end. The opening is closed by a cover that is secured to the throttle body by way of a plurality of fasteners forming a static seal. However, there are known problems with such static seals as well. For example, the sensor may be used for controlling the amount of fuel applied to the combustion chamber of an internal combustion engine. In any such environment the fasteners may loosen over time, thus degrading the static seal and, in turn, the sensor.

Another problem with contact type sensors is that they are subject to wear. In particular, the wipers are known to move back and forth in contact across the thick film resistor a relatively large number of times over the expected lifetime of the sensor; perhaps millions of times. Such moving contact causes localized reductions of the thickness of the thick film resistor. Since resistance is a function of cross-sectional area, the reduction of the resistor thickness will change the local resistance value in the portion of the resistor which experiences the greatest amount of wear. As such, this causes drift of the output over time which affects the calibration and linearity of the sensor. There are other problems with such contact sensors. For example, in some situations, for instance when the engine is run at a nearly constant speed, engine induced vibration can cause additional localized resistor wear, which, as discussed above, can affect the calibration and linear output of the sensor.

In an attempt to overcome the problems accociated with such contaact type angular position sensors, non-contact sensors have been developed. Moreover, due to the relatively hostile environment of an internal combustion engine, various magnetic sensors have been developed. For example, US-A-3,118,108, US-A-4,392,375 and US-A-4,570,118 disclose magnetic angular position sensors which include two magnets and a magnetically sensitive device, such as a Hall effect device or a magneto-resistor. However, there are various known problems with such sensors which utilize two magnets. For example, such sensors are relatively more expensive than sensors which utilize a single magnet. Also, calibration of such sensors is relatively difficult. In particular, conventionally available magnets are generally provided in quantity with tolerance ranges of about ten percent. A second magnet doubles the range of potential variability and thus makes calibration still more difficult.

Other known angular position sensors avoid the problems of two magnet sensors and utilize a single magnet and a magnetically sensitive device, such as a Hall effect device, for example, as disclosed in US-A-3,818,292, US-A-3,112,464, US-A-4,893,502 and US-A-4,570,118. Such single magnet angular position sensors rely on a varying air gap to vary the magnetic flux density applied to the Hall effect device in response to angular motion. However, the varying air gap of such sensors causes the output signal of the sensor to be exponential and thus relatively nonlinear. In order to linearize the response, the magnets utilized with such sensors are known to be formed by various known foundry casting methods in a way to have irregular shapes. However, such cast magnets are known to be rough, having imperfections in their surfaces which contribute to part-to-part variation. The process for removing such imperfections is relatively time-consuming and thus adds significantly to the overall cost of the sensor.

Other known single magnet angular position sensors with a varying air gap utilize irregular-shaped magnet holders for skewing the position of the magnet relative to the rotational axis and the Hall effect element. Such irregular-shaped magnet holders again add to the overall cost of the sensor

and also make the sonsor relatively difficult to calibrate.

Angular position sensors which utilize a single magnet and a non-varying air gap are also known, for example, as disclosed in the aforementioned US-A-4,893,502. The angular position sensor disclosed therein includes a single magnet and a magnetic resistance element (MRE). In this embodiment, a circular magnet is rigidly secured directly to a butterfly valve shaft. The MRE is disposed within a modified throttle body at a fixed air gap relative to the circular magnet. An amplifying circuit with variable gain is used to calibrate the sensors by way of potentiometers or variable resistors. As is known in the art, the output of such potentiometers may vary with temperature or time. Due to the relatively wide operating temperature range of such a sensor in an internal combustion environment, for example, such potentiometers will drift and affect the overall calibration of the device. Another problem with such an arrangement is that the electrical connection between such a potentiometer and the amplifier circuit is known to be made by relatively large macro-scale electrical tracings on a printed circuit board which would be physically large enough to act as an antenna, thus making the circuit relatively susceptible to electromagnetic interference (EMI) and especially radio frequency interference (RFI). As such, the amplifying circuitry would have to be shielded which adds to the cost of the sensor.

This in mind, the invention as claimed primarily solves the problem of avoiding electrical adjusting means in a non-contact angular position sensor. Additional advantages are obtained by complemental features as stated in the dependent claims, these advantages being, for example:

The sensor utilizes a single magnet.

It utilizes a fixed air gap.

It may provide a generally linear output over a relatively wide temperature range.

It may include provisions for self-temperature compensation.

It may be provided with a hermetic seal that is virtually unaffected by wear or vibration.

Briefly, in a preferred embodiment, an angular position sensor in accordance with the present invention includes a magnetically sensitive device, such as a Hall effect IC, and a plurality of flux concentrators, rigidly disposed relative to the Hall effect IC, forming an assembly. The assembly is disposed in a housing a fixed distance from a rotatably mounted standard magnet defining a fixed air gap therebetween. The magnet is disposed in a rotatably mounted magnet holder which also acts as a drive arm that is adapted to be mechanically coupled to a rotatably mounted device in a way to permit a hermetic seal of the sensor. The configuration of the flux concentrators assembled to the mechanically sensitive device may cause the output of the Hall effect IC to be generally linear. In order to avoid problems associated with electrically adjustable angular position sensors, the angular position sensor of the present invention is mechanically adjustable. Preferably, an additional flux concentrator, which may have a halo shape, is disposed adjacent the magnet. The sensitivity of the sensor may be adjusted by varying the distance between the additional flux concentrator and the magnet. In one embodiment of the invention, the halo-shaped flux concentrator is formed to provide temperature compensation for the sensor.

In the following, embodiments of the present invention are described by way of example taking reference to the attached drawings. Therein

FIG. 1 is a sectional view, partially broken away, of a throttle body with an angular position sensor in accordance with the present invention attached thereto;

FIG. 2 is a simplified perspective view of the angular position sensor in accordance with the present invention;

FIG. 3 is a plan view of the angular position sensor illustrated in FIG. 2;

FIG. 4 is a simplified plan view of the angular position sensor in accordance with the present invention illustrating the relationship between the angular position sensor and the magnetic flux in a static position;

FIGS. 5 and 6 are similar to FIG. 4 and illustrate the relationship between the angular position sensor and the magnetic flux in various operating positions;

FIG. 7 is an exemplary graph illustrating the relationship between the output voltage of the angular position sensor versus degrees of rotation shown in dotted line with a superimposed curve which illustrates the effects of the flux concentrators in accordance with the present invention;

FIG. 8 is a perspective view of a pair of flux concentrators which form a portion of the present invention;

FIG. 9 is an elevational view of an alternate embodiment of the flux concentrators illustrated in FIG. 8;

FIG. 10 is an elevational view of a halo-shaped flux concentrator which forms a portion of the present invention;

FIG. 11 is a perspective view of one embodiment of a carrier assembly in accordance with the present invention, shown with a flux concentrator removed;

FIG. 12 is a perspective view of the assembly illustrated in FIG. 11 in a further stage of development;

FIG. 13 is a cross-sectional view of an angular position sensor incorporating the carrier assembly illustrated in FIGS. 11, and 12; and

FIG. 14 is an exploded perspective view of an alternate embodiment of the angular position sensor in accordance with the present invention.

FIG. 15 is a perspective view of a flux concentrator in accordance with the present invention;

FIG. 16 is a perspective view of an alternate embodiment of the angular position sensor illustrated in FIG. 1; and

FIG. 17 is a cross sectional view in elevation of the angular position sensor illustrated in FIG. 16.

With reference to FIG. 1, an angular position sensor 20 in accordance with the present invention is disposed in a housing of its own, identified as 22, and includes a drive arm 24, rotatably mounted relative to the housing 22 and enabling the sensor 20 to be mechanically coupled to an output shaft of a pivotally mounted device. In an application as shown in FIG: 1, such as a throttle position sensor, the drive arm 24 is mechanically coupled to a butterfly valve shaft 26 carried by a throttle body 27. More particularly, in such an application, a butterfly valve 28 is rigidly affixed to the rotatably mounted shaft 26 with suitable fasteners 30 or by spot welding. The shaft 26 is rotatably mounted relative to a throttle body 27 with suitable bearings 34.

The butterfly valve 28 is formed to close or throttle the air flow to an internal combustion engine (not shown). By coupling the angular position sensor 20 to the butterfly valve shaft 26, the angular position sensor 20 is adapted to provide an electric signal representative of the angular position of the butterfly valve 28 for use e.g. in controlling the amount of fuel applied to the combustion chamber in an internal combustion engine. However, it should be appreciated that the application of the angular position sensor 20 in accordance with the present invention is also useful for various other applications.

As shown, the butterfly valve shaft 26 is formed with a reduced cross-sectional area portion or tongue 36 which extends outwardly from one side of a throttle body 27 to allow engagement with the drive arm 24. In order to prevent rotation of the tongue 36 relative to the drive arm 24, the tongue 36 may be formed with a non-circular cross-section that is adapted to mate with a cooperating recess 38 formed in the drive arm 24.

Sensor 20 is formed as a separate unit that is adapted to rather quickly and easily be secured to, for example, the throttle body 27 by way of suitable fasteners 40. By providing the angular position sensor 20 as a separate unit, the calibration of the sensor 20 can be done at the factory by the sensor manufacturer. In contrast, some known angular position sensors are incorporated directly into the throttle body, for example, as disclosed in U.S. Patent No. 4,893,502. In such an embodiment, calibration of the sensor is normally done by the throttle body manufacturer whose experience with such sensors is admittedly less than the sensor manufacturer.

FIGS. 2 and 3 illustrate the basic principle of the angular position sensor 20. In particular, the angular position sensor 20 includes a magnet 42, preferably a standard bar-shaped magnet defining opposing North and South magnetic poles, a magnetic sensing element 43, a pair of generally L-shaped flux concentrators 44 and 46 and an additional flux concentrator 48, used for adjustment. As will be discussed in more detail below, the magnet 42 is adapted to be mounted in the drive arm 24 for rotation about an axis 50 (FIG. 1) that is generally perpendicular to a magnetic axis 52 which interconnects the opposing North and South magnetic poles, as shown in FIG. 1. As will be discussed in more detail below, the magnet 42 is mounted within the drive arm 24 such that the axis of rotation 50 of the magnet is coaxial with the butterfly valve shaft 26 and generally perpendicular to the magnetic axis 52 such that rotation of the butterfly valve shaft 26 causes rotation of the magnet 42 about the axis 50 by a corresponding amount.

The magnetic sensing element 43 is preferably a Hall effect IC with on-chip amplifier circuits, for example, an Allegro Model No. 3506. Since the angular position sensor 20 is adjusted mechanically there is no need for external circuitry for electrically adjusting the sensor 20. As such, the output of the magnetic sensing device 43 is adapted to be directly coupled to the fuel control circuit (not shown) for the internal combustion engine. By eliminating the need for external potentiometers or variable resistors, the need for conductive tracings on a printed circuit board to connect the magnetic sensing device 43 to such external potentiometers or variable resistors is eliminated.

As best shown in FIG. 13, the magnetic sensing element 43 is mounted stationary relative to the housing 22 at a fixed air gap 54 relative to a surface 58 of the magnet 42 that is generally parallel to the magnetic axis 52. The generally L-shaped flux concentrators 44 and 46 are rigidly disposed relative to the magnetic sensing device 43 forming an assembly 60. In particular, the magnetic sensing device 43 is sandwiched between the generally L-shaped flux concentrators 44 and 46 to form the assembly 60. The assembly 60 is disposed such that a sensing plane 62, defined by the magnetic sensing element 43, is generally parallel to the axis of rotation 50 of the magnet 42. As

shown, a Hall effect IC is used as the magnetic sensing element 43. In such an embodiment, the sensing plane 62 is defined as a plane generally parallel to opposing surfaces 64 and 66, shown in FIG. 4.

As shown in FIG. 2, the assembly 60 is disposed such that the axis of rotation 50 of the magnet 42 is through the midpoint of the magnetic sensing device 43 and parallel to the sensing plane 62. However, it is also contemplated that the assembly 60 can be disposed such that the axis of rotation 50 is offset from the midpoint of the magnetic sensing element 43 along an axis generally parallel to the sensing plane 62.

As shown in FIG. 4, the angular position sensor 20 is in a quiescent state. In this state the magnetic flux density B, represented by the arrows identified with the reference numeral 68, is generally parallel to the sensing plane 62 of the magnetic sensing device 43. In this state the magnetic sensing element 43 outputs a quiescent voltage. For an Allegro Model No. 3506 Hall effect IC, the quiescent output voltage is typically about 2.5 volts DC. Rotating the magnet 42 counterclockwise as shown in FIGS. 5 or 6 or clockwise (not shown) causes an ever increasing amount of magnetic flux density 68 to be applied to the sensing plane 62 of the magnetic sensing element 43 to vary the output voltage of the magnetic sensing element 43 as a function of an angle θ defined between an axis 63 parallel to the sensing plane 62 and an axis 65. For an Allegro Model No. 3506, the output voltage swing is approximately ±2.0 volt DC depending on the direction of the angular rotation.

The relationship between the axes 63 and 65 can be varied in order to adjust the offset voltage of the sensor 20. In particular, the assembly 60 is rotated relative to the magnet 42 in a quiescent state to adjust the sensor offset voltage. In such an application, the sensor would be configured in the quiescent state to have a small angle θ between the axes 63 and 65 as illustrated in FIG. 4.

As will be discussed in more detail below, the output voltage of the angular position sensor 20 varies linearly as a function of the angular rotation of the magnet 42. As such, the output voltage of the angular position sensor 20 can be applied directly to the fuel consumption circuit for the internal combustion engine without the need for additional and expensive external circuitry. In particular, known angular position sensors have utilized various circuitry including microprocessors to linearize the output voltage, which adds to the complexity and cost of the sensor. The angular position sensor 20 in accordance with the present invention eliminates the need for such external circuitry. In particular, the output signal is linearized by way of the generally L-shaped or book-end type flux concentrators 44 and 46, which not only direct the magnetic flux and control the density and polarity of the magnetic flux density but also linearize the output signal to near straight line form. As such, the angular position sensor 20, in accordance with the present invention, is adapted to be substituted for potentiometer-type throttle position sensors which are contact devices with a finite life. More particularly, FIG. 7 illustrates a graph of the output voltage of the angular position sensor 20 as a function of the degrees of rotation. The solid line 72 represents the output of the angular position sensor 20 without the book-end shaped flux concentrators 44 and 46. As shown, the output voltage of such an embodiment varies relatively non-linearly relative to the degrees of rotation. By incorporating the book-end shaped flux concentrators 44 and 46, the output voltage of the angular position sensor 20 becomes fairly linear. More particularly, the solid line 74 represents the desired relationship between the output voltage of the angular position sensor 20 versus the degrees of rotation of the magnet 42. The dashed line 76 represents the output voltage of the sensor 20 which incorporates the book-end shaped flux concentrators 44 and 46. As illustrated, the dashed line 76 is fairly linear over the anticipated operating range of the sensor, for example, 110° rotation.

The book-end shaped flux concentrators 44 and 46 are formed from a magnetically soft material - a magnetically permeable material which does not retain residual magnetism. Various configurations of the book-end shaped flux concentrators 44 and 46 are contemplated, for example, as shown in FIGS. 8 and 9. Referring to FIG. 8, the book-end flux concentrators 44 and 46 are formed in a generally L-shape defining two depending leg portions 78 and 80. The outer intersection of the depending legs 78 and 80 defines a heel portion 82. The inner intersection of the depending legs 78 and 80 defines a generally arcuately-shaped inner portion 84. It is also contemplated that the inner portion 84 may be formed such that the depending leg portions 78 and 80 are virtually perpendicular at the point of intersection or have a predetermined radius of curvature as illustrated in FIG. 8. In the preferred embodiment illustrated in FIG. 9, the flux concentrators 44 and 46 are formed in a similar manner as the flux concentrators illustrated in FIG. 8 but with the heel portion 82 removed and a relatively larger radius of curvature for the inner portion 84.

In accordance with the present invention, the sensor 20 allows the sensitivity (e.g. volts/degree of rotation) of the sensor 20 to be adjusted mechanically. As discussed above, various known sensors utilize potentiometers or variable resistors and the like for varying the sensitivity of the sensor. How-

ever, such sensors are relatively temperature dependent. Thus, in a relatively hostile environment where the temperature is anticipated to vary over a relatively wide range, the calibration of such sensors is known to drift. The angular position sensor 20 in accordance with the present invention solves this problem by providing a method for mechanically adjusting the sensitivity of the sensor without the need for potentiometers and the like. In the embodiment here described this is obtained by an additional flux concentrator 48. Although the flux concentrator 48 is described and illustrated having a halo or washer shape, as illustrated in FIG. 2, for example, it is to be understood that various shapes for the flux concentrator 48 are contemplated. For example, a rectangular shape may be used for the flux concentrator as illustrated and identified with reference numeral 48' in FIG. 15. In such an embodiment, various means within the ordinary skill in the art are contemplated for supporting the flux concentrator 48 relative to the magnet 42.

In the preferred embodiment, the flux concentrator 48 is formed in a generally circular or halo shape with a centrally disposed aperture 86. The flux concentrator 48 is adapted to be disposed such that the midpoint of the aperture 86 is generally coaxial with the axis of rotation 50 of the magnet 42. The sensor's sensitivity is adjusted by varying the distance between the flux concentrator 48 and the magnet 42 in an axial direction relative to the axis of rotation 50 as indicated by the arrows 88 (FIG. 2). It is contemplated that the plane of the flux concentrator 48 be generally parallel to the plane of the magnet 42. The halo-shaped flux concentrator 48 thus provides a mechanical and relatively stable method for adjusting the sensitivity of the sensor 20 utilizing a relatively inexpensive and until now often impractical class of linear IC; impractical because of the relatively wide range of part-to-part electrical output values of offset voltage and sensitivity per gauss.

In an alternate embodiment as illustrated in FIG. 10, the flux concentrator 48 is formed to be self-temperature compensating. In this embodiment, the flux concentrator 48 may be formed in a plurality of layers. Three layers are shown for example. The outer layers 90 are formed from a first material, for example, an iron-nickel alloy comprised of approximately 29%-33% nickel. The inner layer 92 is formed from low carbon steel, for example, C1008 low carbon steel. With such an embodiment, the properties of the nickel alloy used in the outer layers 90 cause the permeability of the outer layers 90 to decrease with an increase in temperature which decreases the ability of the flux concentrator 48 to concentrate magnetic flux as a function of temperature. Thus, as the temperature increases, the magnetic flux concentrator 48 captures less of the magnetic field causing a relatively greater portion of the magnetic field to be applied to the magnetic sensing element 43 during such a condition. Thus, since it is known that the magnetic field intensity of known magnets weakens as a function of temperature, the magnetic flux concentrator 48 illustrated in FIG. 10 allows a greater percentage of the magnetic flux density 68 to be applied to the magnetic sensing element 43 during relatively high temperature conditions and is thus self-temperature compensating.

FIGS. 11 and 12 illustrate a carrier assembly 94 for carrying the magnetic sensing device 43 as well as the magnetic flux concentrators 44, 46 and a halo-shaped flux concentrator 48. In particular, FIG. 11 illustrates the carrier assembly 94 with the halo-shaped flux concentrator 48 removed. The carrier assembly 94 includes a disk-shaped base portion 96 and a generally T-shaped frame portion 98. The T-shaped frame portion 98 defines a pair of depending legs 100 and 101, disposed generally perpendicular to the plane of the base portion 96, interconnected by a connecting member 102. A stud portion 104 is formed to extend outwardly from the connecting member 102. The stud portion 104, as will be discussed in more detail below, is used for adjusting the distance between the halo-shaped flux concentrator 48 and the magnet 42. In alternate embodiments of the invention where a configuration other than a halo shape is used for the additional flux concentrator, for example, a rectangular shape, as illustrated in FIG. 15, the stud portion 104 is unnecessary and thus eliminated and substituted with a suitable arrangement for supporting such a flux concentrator 48' relative to the magnet 42.

Referring back to the preferred embodiment, the halo-shaped flux concentrator 48 is shown with a generally star-shaped aperture 86. In such an application, the diameter of the stud 104 is formed to provide a friction fit with the irregular-shaped aperture 86 to allow the sensitivity of the sensor 20 to be adjusted by way of axial movement of the flux concentrator 48 relative to the magnet 42. In an alternate embodiment of the invention, it is contemplated that the stud 104 and the aperture 86 be threaded to enable the distance between the flux concentrator 48 and the magnet 42 to be varied by rotating the flux concentrator 48.

The book-end type flux concentrators 44 and 46 are disposed intermediate the depending legs of the T-shaped frame 98 to enable the magnetic sensing device 43 to be sandwiched therebetween. As shown best in FIG. 14, the magnetic sensing device 43 is a three wire Hall effect IC. This magnetic sensing device 43 is adapted to be connected to a flexible printed circuit board 106 (FIG. 12) and wrapped around the frame 98 as best illustrated in

FIG. 12. Opposing fingers 105 may also be formed in the depending leg portions 100 and 101 to capture a portion of the printed circuit board 106 as shown. A terminal structure 107 is then connected to the printed circuit board 106 to enable the sensor 20 to be connected to an external electrical conductor (not shown). The terminal structure 107 is shown in FIG. 12 with bridging members 109, which are removed to form three electrical terminals 111, 113 and 115. The carrier assembly 94 complete with the printed circuit board 106 is then assembled to the housing 22 as illustrated in FIG. 13.

An alternate embodiment of the sensor is illustrated in FIG. 14, identified with the reference numeral 20'. In this embodiment, like components are identified with the same reference numerals and are distinguished with primes. The housing 22' is formed as an irregular-shaped housing with a central aperture 108 for receiving the drive arm 24. As best shown in FIG. 1, the drive arm 24 is formed with a centrally disposed aperture 110 on one end (FIG. 1) that is keyed or otherwise adapted to rotate with the butterfly valve shaft 26 defining a drive arm portion 123 (FIG. 14). The other end of the drive arm 24 is provided with a generally rectangular aperture 112 defining a magnet holder portion 121 for receiving the magnet 42. The drive arm 24 is adapted to be received in the aperture 108 formed in the housing 22'. The drive arm 24 may be formed with an integral washer 114 with an extending tongue 116. The tongue 116 cooperates with stops 118 formed within the aperture 108 which are radially disposed to limit the rotation of the drive arm 24 relative to the housing 22'. As will be appreciated by those of ordinary skill in the art, the location of the stops 118 within the aperture 108 are provided to coincide with the expected angular rotation of the device whose angular position is being sensed. As mentioned above, when the angular position sensor 20 in accordance with the present invention is used as a throttle position sensor, the stops 118 are provided to allow for about 110° of rotation. In alternate embodiments of the invention, the housing 22 may be formed without the stops 118 to enable a full 360° of isolation for the sensor 20.

The drive arm 24 may be biased by a torsion spring 120 having extending end portions 122. The bottom end portion (not shown) is adapted to be received in a slot 124 formed in the aperture 108. The top end portion 122 is received in a corresponding slot 126 formed in the drive arm 24. The diameter of the torsion spring 120 is sized to be slightly larger than the magnet holder portion 121. In embodiments wherein the sensor is adapted to rotate 360°, the torsion spring 120 is eliminated.

The aperture 108 is formed with concentric walls 128, 130 and 132. The concentric wall 128 only spans a portion of the circumference of the aperture 108 to form the stops 118 as discussed above. The drive arm portion 123 is received within the aperture 108 to allow rotational movement of the tongue 116 relative to the stops 118, formed in the partial concentric inner wall 128. The magnet holder portion 121 is received in an integrally formed circular guide, 134 formed on the underside of the carrier 94'. Once the drive arm 24 and torsion spring 120 are disposed within the aperture 108, the carrier assembly 94 closes the aperture 108 by way of an O-ring 158 forming the angular position sensor in accordance with the present invention. As shown, the carrier 94' and printed circuit board 106' are configured differently than the embodiment illustrated in FIGS. 11-13.

As shown, the printed circuit board 106' may include three conductive tracings 132 for connecting the electrical conductors 144 from the magnetic sensing element 43 thereto. A pair of capacitors 138, preferably surface mount capacitors, are electrically connected with the conductive tracings 132 to suppress noise-to-ground. Three plated-through holes 140 are provided for connecting the conductors 144 of the magnetic sensing device 43 to the printed circuit board 106'. The printed circuit board 106' includes an additional three plated-through holes 142 for connection with corresponding terminals 148, insert molded into the housing 22', which enables the sensor 20' to be connected to an external electrical conductor (not shown). Once the components of the sensor 20' are assembled, the component side 146 of the sensor 20' is then potted with a suitable potting compound, such as epoxy to seal the electrical components. This allows the electrical components of the sensor to be sealed from moisture, contaminants and the like without the need for a dynamic or a static seal as discussed above. As such, the seal in accordance with the present invention is virtually unaffected by wear or vibration.

As discussed above, the angular position sensor 20, 20' is connected to a throttle body 27 by way of the fasteners 40. Thus, the housing 22, 22' may be provided with a pair of oppositely disposed apertures 154 for receiving a pair of insert molded mounting sleeves 156. The fasteners 40 are received in the mounting sleeves 156 and are used to connect the sensor 20, 20' to the throttle body 27.

An alternate embodiment of the throttle position sensor is illustrated in FIGS. 16 and 17 and generally identified with the reference numeral 200. This throttle position sensor 200 includes a magnet 202, a magnetic sensing element 204, one or more flux concentrators 206 rigidly secured relative to

the magnetic sensing element 204 and a movably mounted flux concentrator 208 which enables the throttle position sensor 200 to be adjusted mechanically without the need for potentiometers and the like. In this embodiment, the magnet 202 is carried by a drive arm assembly 210 rotatably mounted relative to the magnetic sensing element 204 and the stationary mounted flux concentrators 206 and 208. As shown by the direction of the arrows 212, the magnet 202 is adapted to rotate about an axis 214.

The magnet 202 is formed as a generally circular element with a center aperture 216. The magnet 202 is formed such that each semicircular portion forms a pole. In particular, a semicircular portion 218 forms a south pole, while a semicircular portion 220 forms a north pole.

The magnetic sensing element 204 and the rigidly mounted flux concentrators 206 are carried by a housing 221; the housing 221 being formed from a non-magnetically conductive material; for example, plastic, brass or aluminum. In particular, the housing 221 as best shown in FIG. 17 is formed with a generally cylindrical portion 222 closed on one end 224 and an annular skirt portion 226. The magnetic sensing element 204 may be sandwiched between the rigidly mounted flux concentrators 206 and carried by the closed end 224 of the cylindrical portion 222 of the housing 221. A notch 228 may be formed in the closed end 224 for capturing the magnetic sensing element 204 to facilitate proper orientation of the magnetic sensing element 204 relative to the housing 221.

The outer diameter of the cylindrical portion 222 of the housing 221 may be formed to be relatively smaller than the diameter of the centrally disposed aperture 216 in the circular magnet 202. Such a configuration enables the cylindrical portion 222 of the housing 221 to be disposed within the aperture 216 in order to reduce the overall axial length of the sensor 200.

A cover 230 is provided and adapted to be rigidly secured to the throttle body 27 (FIG. 1) in a similar manner as discussed above. The cover 230 is formed as a generally cylindrical member with at least a partial interior annular shoulder 232 and a mouth portion 234. The annular shoulder 232 defines a first interior diameter and a second interior diameter. The first interior diameter is selected to be slightly larger than an outer diameter of the skirt portion 226 of the housing 221. An O-ring 227 may be used to seal the housing 221 relative to the cover 230 to prevent the potting material from getting into the area of the drive arm 235. The O-ring 227 may be disposed in an annular notch 229 formed in the housing 221.

The second interior diameter of the cover 230 is relatively smaller than the first interior diameter. The size of the second interior diameter of the cover 230 is selected to enable the drive arm assembly 210 to rotate freely therewithin.

The drive arm assembly 210 includes a drive arm 235 formed as an annular member with an irregular shape defining an annular well portion 236 and a drive portion 238. The annular well portion 236 is formed to receive the cylindrical portion 222 of the housing 221 to enable the overall axial length of the sensor 200 to be reduced in a manner as discussed above. The drive portion 238 is adapted to be coupled to the throttle shaft 26 in a manner as discussed above such that the drive arm assembly 210 rotates with the throttle shaft 26.

A helical spring 240 is used to bias the drive arm assembly 210 to a predetermined position, for example, the position shown in FIG. 17. In particular, a helical spring 240 is disposed about the outer diameter of the drive arm 235. One end (not shown) of the helical spring 240 is rigidly secured to the drive arm 235. The other end 242 of the spring 240 is rigidly secured to the cover 230. As such, rotation of the drive arm assembly 210 relative to the cover 230 can cause compression or tension of the spring 240 to bias the drive arm assembly 210.

The well portion 236 of the drive arm 235 is formed with an interior annular shoulder 243. The dimensions of the annular shoulder 243 are selected to enable the circular magnet 202 to be flush with an interior annular wall 244 of the drive arm 235.

The sensor 200 also includes a printed circuit (PCB) 245. The PCB 245 is carried by the cylindrical portion 222 of the housing 221 for providing an electrical path between the magnetic sensing element 204 and a set of external electrical leads 246. In particular, if a Hall effect device is used for the magnetic sensing element 204, such a device will have a plurality of electrical leads 248. The PCB 245 is formed to provide an electrical path between the electrical leads 246 and 248 in a manner as discussed above.

The offset voltage of the sensor 200 is adjusted in a similar manner as discussed above; namely, rotating the cylindrical portion 221 and the sensing plane of the magnetic sensing element 204 with respect to the magnet 202.

The sensitivity of the sensor 200 is adjusted by varying the axial distance between the flux concentrator 208 and the magnetic sensing element 204. As best shown in FIG. 17, the flux concentrator 208 is carried by the cylindrical portion 222 of the housing 221 with a slight friction or interference fit to enable the axial distance relative to the magnetic sensing element 204 to be varied. More specifically, the flux concentrator 208 is formed in a generally circular shape with a central aperture

250. The diameter of the central aperture 250 is selected to be slightly smaller than the outer diameter of the cylindrical portion 222 of the housing 221 to enable the flux concentrator 208 to be carried thereby in order to enable the axial distance between the flux concentrator 208 and the magnetic sensing element 204 to be varied. Once the axial distance of the flux concentrator 208 is set, a portion of the housing 221 is potted with a suitable potting material 249, such as epoxy, to seal the assembly from dust, moisture and other harmful contaminants. The annular skirt portion 226 of the housing 221 protects the bottom portion (FIG. 17) from the potting material 249 in order to allow the drive arm assembly 210 to rotate freely.

In operation, rotation of the throttle shaft 26 causes rotation of the drive arm assembly 210. Since the magnet 202 is rigidly secured to the drive arm assembly 210, such rotation will cause the relative angular position of the north and south magnetic poles 202 to vary relative to a sensing plane of the magnetic sensing element 204. Such a change will cause the output signal from the magnetic sensing element 204 to vary as a function of the change in angular position of the magnet 202 and the throttle shaft 26.

While the invention has been described with reference to details of the embodiments shown in the drawings, these details are not intended to limit the scope of the invention as described in the appended claims.

Claims

1. An angular position sensor (20, 20', 200) for sensing the angular position of a pivotally mounted device (28) about a predetermined pivot axis (50, 214), said angular position sensor (20, 20', 200) including a housing (22, 221); means (24, 210) for providing a mechanical coupling to said pivotally mounted device (28), rotatably mounted relative to said housing (22, 221); a magnet (42, 202) having North and South magnetic poles; and means (43, 204) responsive to said providing means (24, 210) for generating an electrical signal representative of the angular position of said pivotally mounted device (28); CHARACTERIZED BY means (48, 86, 104; 208, 250, 222, FIGS. 4-6) for mechanically adjusting said generating means (43, 204).

2. An angular position sensor (200) as recited in claim 1, wherein said generating means (204) is at least partially disposed between said North and South poles of said magnet (202).

3. An angular position sensor (200) as recited in Claim 1, wherein said magnet (202) is a circular magnet with a central aperture (216) defining two semicircular portions (218, 220) of opposite magnetic polarities.

4. An angular position sensor (200) as recited in Claim 3, wherein said generating means (204) is disposed within said central aperture (216) in said magnet (202).

5. An angular position sensor (200) as recited in Claim 1, wherein said generating means (204) includes a Hall effect device.

6. An angular position sensor (200) as recited in Claim 5, further including one or more flux concentrators (206).

7. An angular position sensor (200) as recited in Claim 1, wherein said adjusting means (208, 250, 222) includes a flux concentrator (208) and means (222, 250) for carrying the flux concentrator (208) a predetermined distance relative to said generating means (204).

8. An angular position sensor (200) as recited in Claim 7, wherein said flux concentrator (208) is formed in a generally halo-shape with a generally, centrally disposed aperture (250).

9. An angular position sensor (200) as recited in Claim 7, wherein said flux concentrator carrying means (222) includes means (222, 250) for enabling the distance between said additional flux concentrator (208) and said generating means (204) to be varied.

10. An angular position sensor (20, 20', 200) as recited in Claim 1, further including means (48, 208) for providing temperature compensation for said sensor (20, 20', 200).

11. An angular position sensor (20, 20') as recited in Claim 1, wherein said magnet (42) is a bar magnet defining opposing North and South poles.

12. An angular position sensor (20, 20') as recited in Claim 11, wherein said generating means (43) is disposed adjacent to said bar magnet (42).

13. An angular position sensor (20, 20', 200) as recited in Claim 10, wherein said temperature compensation providing means includes a flux concentrator (48, 208).

14. An angular position sensor 20, 20', 200) as recited in Claim 13, wherein said flux concentrator (48, 208) is formed from a plurality of materials defining one or more layers (90, 92).

15. An angular position sensor (20, 20', 200) as recited in Claim 14, wherein said one or more of said layers (90, 92) are formed from a material whose permeability decreases at a different rate with increasing temperature relative to the other material layer.

16. An angular position sensor (20, 20', 200) as recited in Claim 15, wherein said one or more of said layers (90, 92) are formed from an iron-nickel alloy.

17. An angular position sensor (20, 20', 200) as recited in Claim 14, wherein said one or more of said layers (90, 92) are formed from steel.

18. An angular position sensor (20, 20', 200) as recited in Claim 1, wherein said adjusting means (48, 86, 104; 208, 250, 222) include means (FIGS. 4-6) for adjusting the sensitivity of said sensor (20, 20', 200).

19. An angular position sensor (20, 20', 200) as recited in Claim 1, wherein said adjusting means includes means (48, 86, 104; 208, 250, 222) for adjusting the offset voltage of said sensor (20, 20', 200).

20. An angular position sensor (20, 20', 200) as recited in Claim 1, further including means (249) for hermetically sealing said sensor (20, 20', 200).

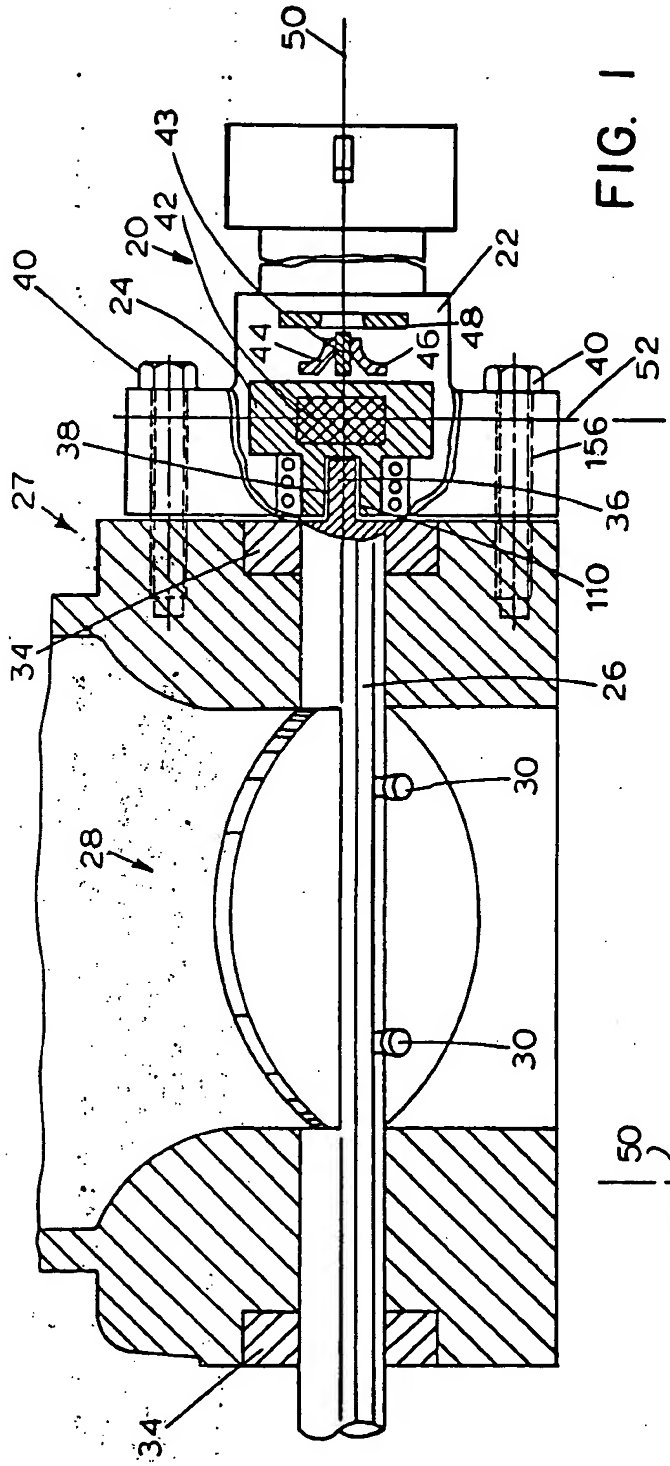

FIG. 1

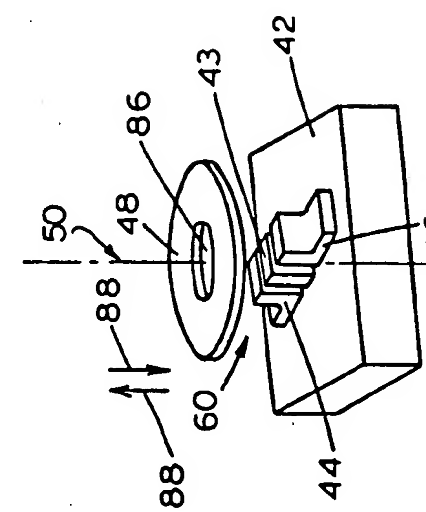

FIG. 2

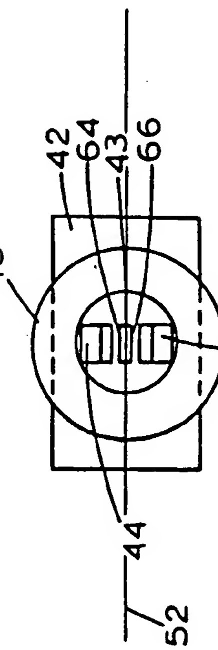

FIG. 3

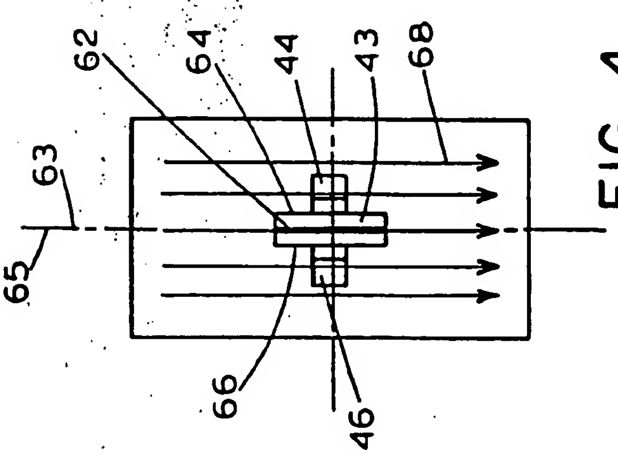

FIG. 4

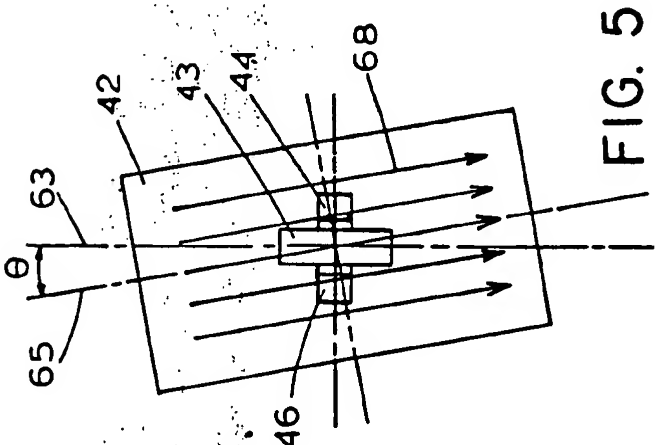

FIG. 5

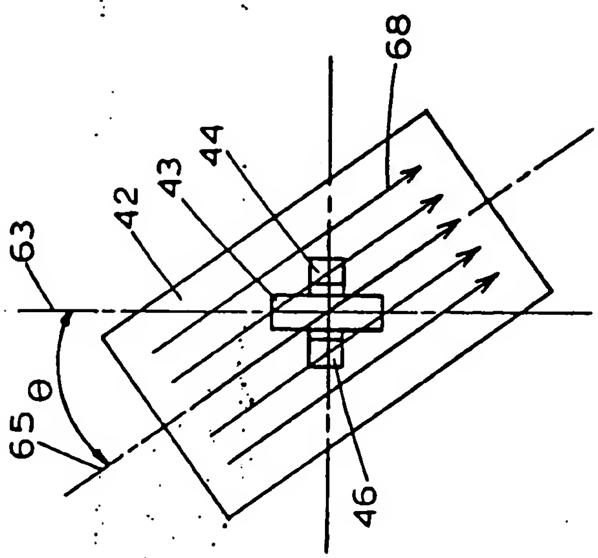

FIG. 6

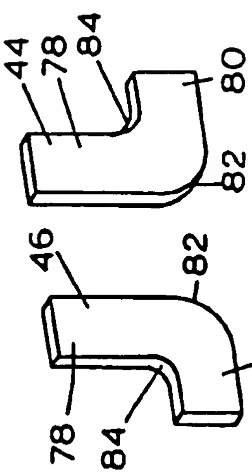

FIG. 8

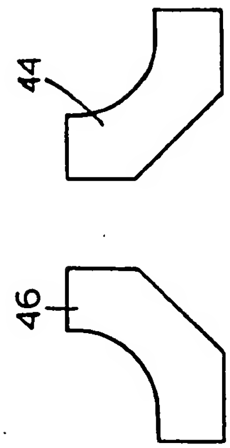

FIG. 9

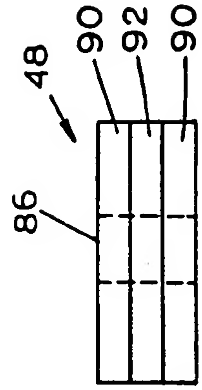

FIG. 10

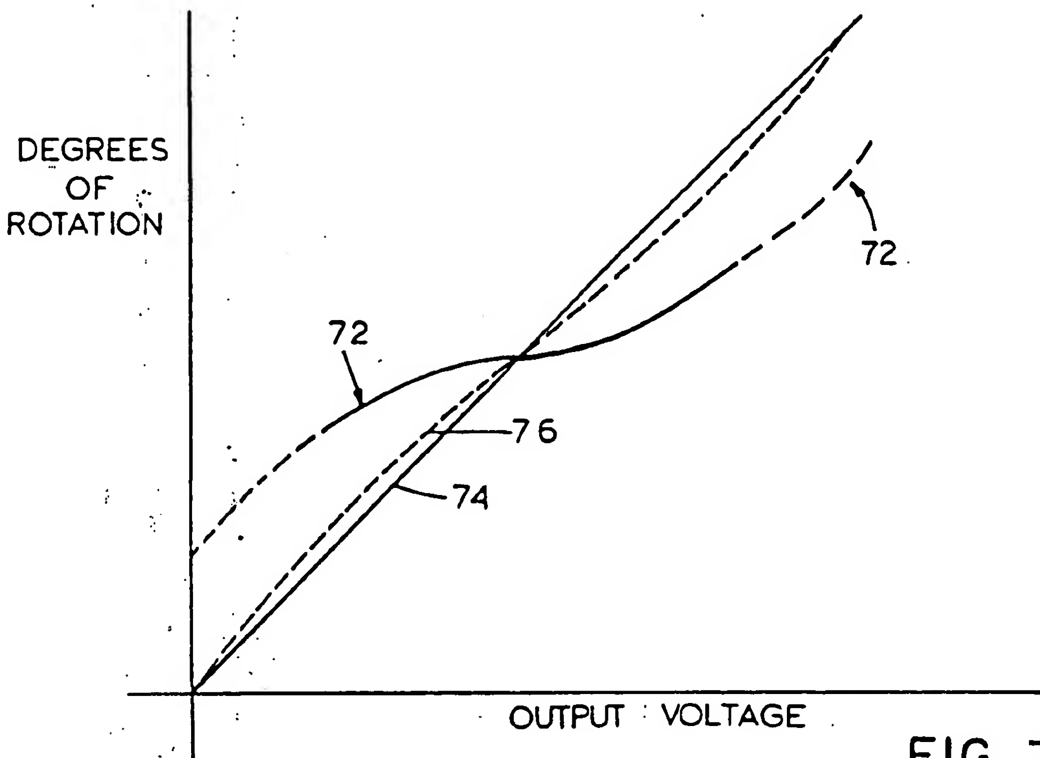
DEGREES
OF
ROTATION
72
76
74
72
OUTPUT VOLTAGE

FIG. 7

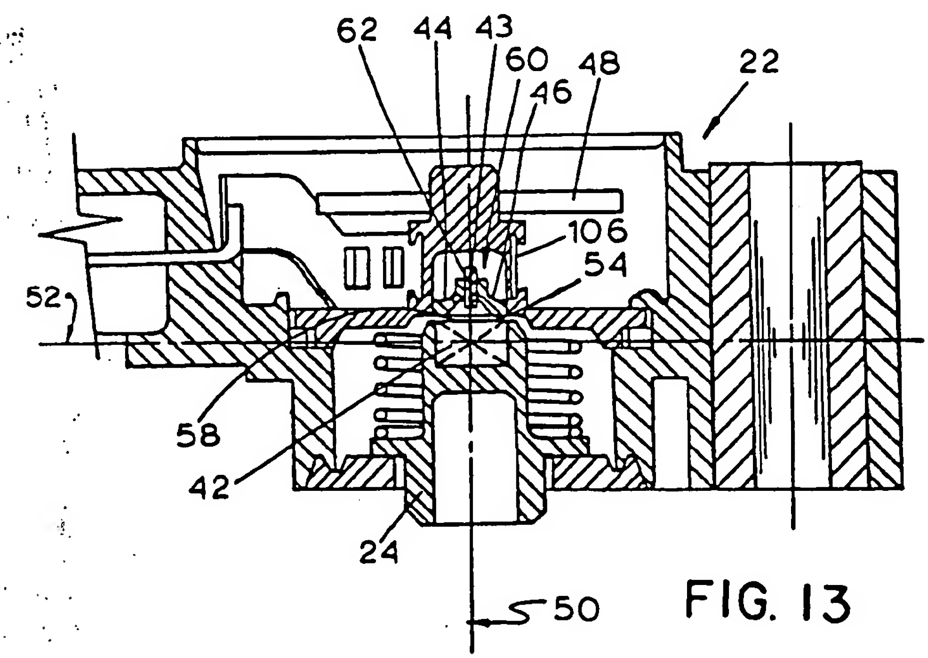
62
44
43
60
48
46
22
106
54
52
58
42
24
50

FIG. 13

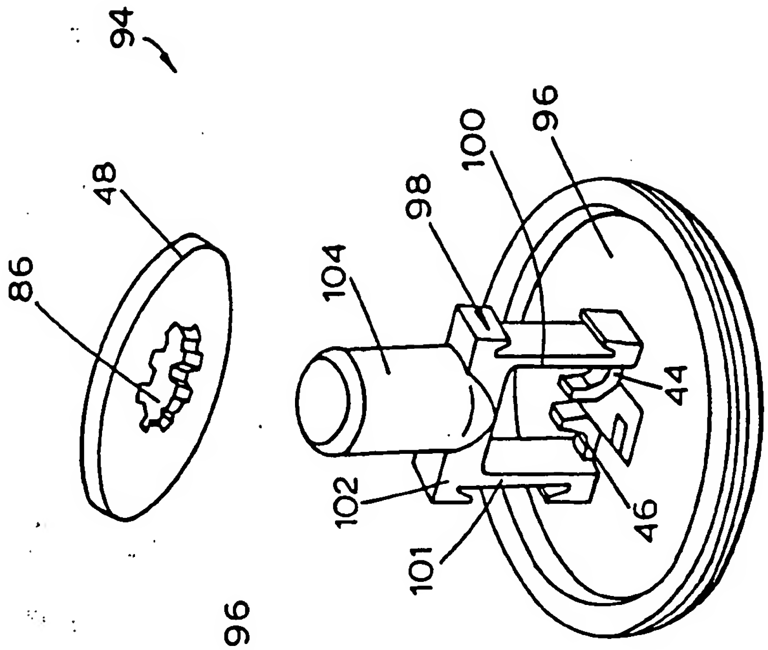
94
48
86
104
98
100
96
44
46
102
101

FIG. 11

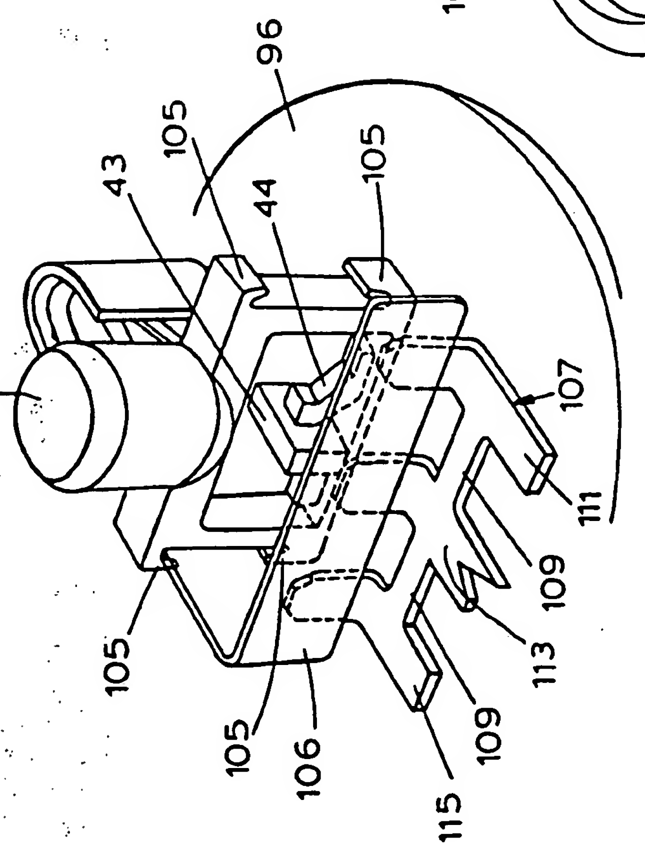
94
104
43
105
44
96
105
107
111
109
113
109
115
106
105
105

FIG. 12

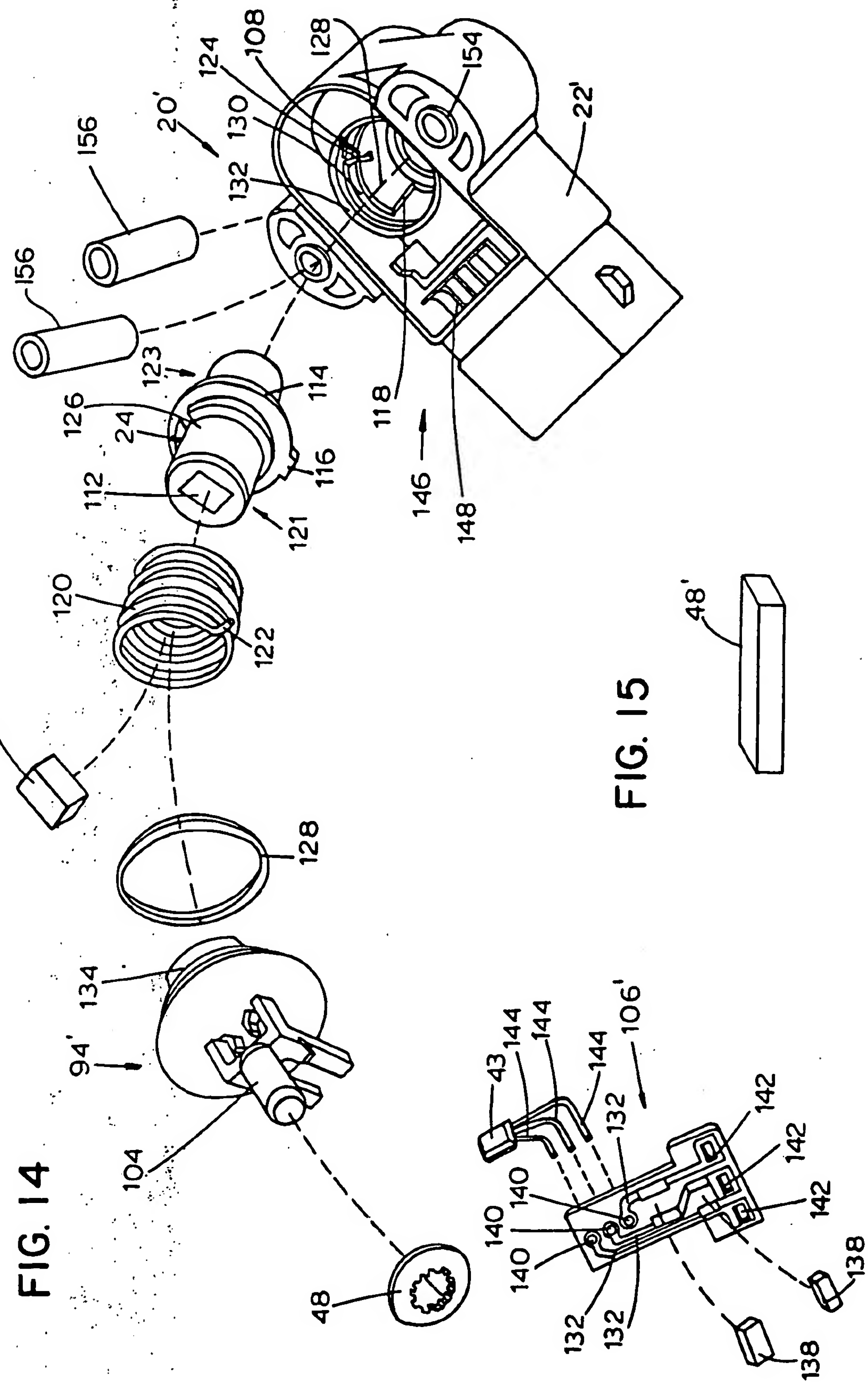
20'
156
156
132
130
124
108
128
154
22'
123
126
24
114
116
112
121
118
146
148
120
122
42
128
134
94'
104
48
43
144
144
144
106'
132
140
140
140
142
142
142
138
138
132
132
48'

FIG. 14

FIG. 15

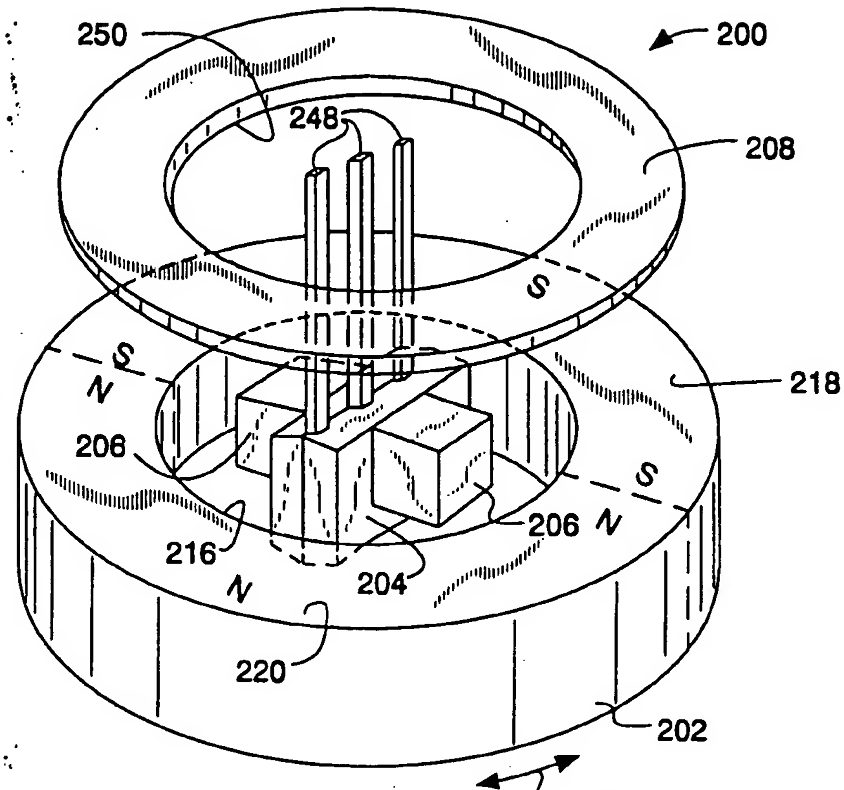
250
200
248
208
S
S
N
218
206
S
206
N
216
204
N
220
202
212

FIG. 16

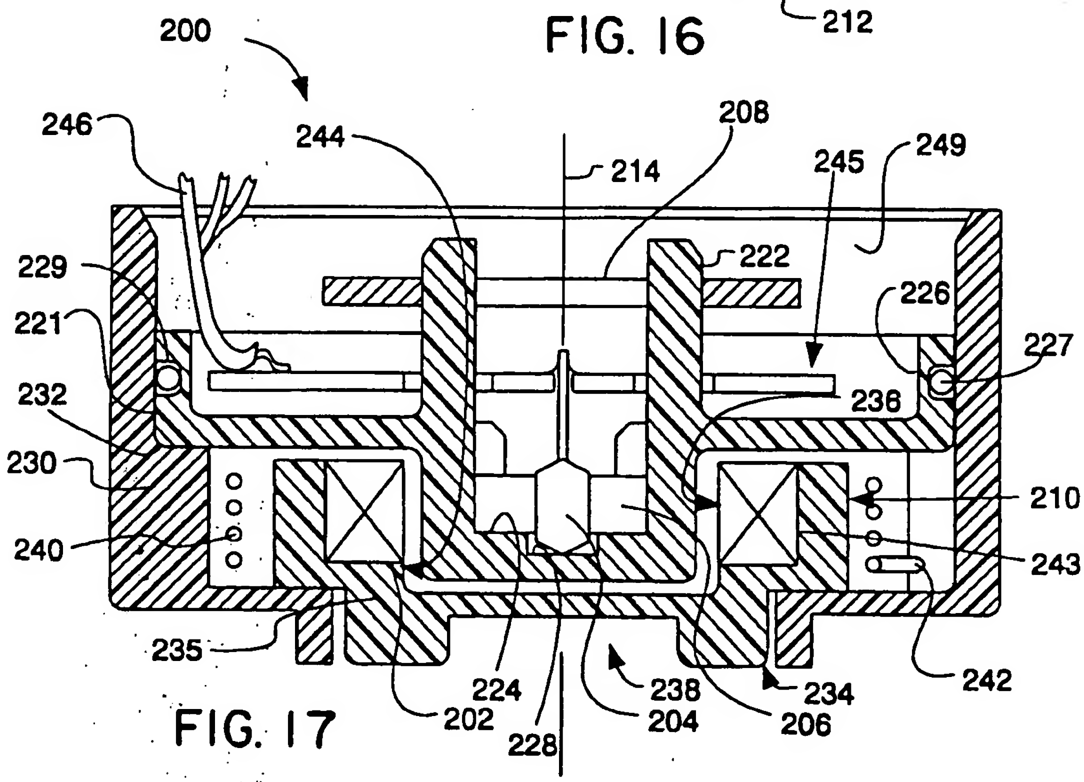
200
246
244
208
214
245
249
229
222
226
221
227
232
236
230
210
240
243
235
224
238
234
242
202
228
204
206

FIG. 17

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 93 11 0001

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
D,X	US-A-4 392 375 (OSAMU EGUCHI ET AL)	1,2, 10-13, 18-20	G01D5/14
	* the whole document *		
Y		3,5-8	

Y	WO-A-8 807 172 (AMPEX) * abstract; figures 2,3 *	3,5	

Y	EP-A-0 363 738 (MITSUBISHI DKK) * the whole document *	6-8	

A	DE-A-4 014 885 (AISAN KKK) * abstract; figure 1 *	4	

D,A	US-A-4 893 502 (MASANORI KUBOTA ET AL) * column 7, line 21 - column 7, line 40; figure 12 *	12	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

G01D
F02D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	21 SEPTEMBER 1993	LLOYD P.A.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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L : document cited for other reasons

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